Parabolic Trough VSHOT Optical Characterization in 2005-2006

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Trough Deployment/Operation Phases

- Development
  - R&D directed at maximizing performance/cost ratio
  - Requires testing tool(s) that provide detailed data on mirror contour, mirror panel positioning
- Manufacture/Installation
  - QC testing of mirror panels (statistical sampling)
  - Module assembly
  - Requires fast, relatively simple optical characterization to reveal problems & fix
- Maintenance/Operation
  - Many contributors to optical performance (e.g. specularity, mirror distortion, dirt, receiver shape/position)
  - Large fields require simple, fast, effective tools to understand/fix problems & maximize performance

Optical Characterization Areas

- Mirror Optical Accuracy
  - Mirror contour
  - Mirror specularity
- Mirror Panel Alignment
  - Tilt
  - Position
- Receiver Positioning

Each issue is uniquely present in each phase

Trough Optical Characterization Issues

- Single biggest challenge to fast, effective characterization:
  - Lower concentration, line focus optics a large mirror area and subsequent spatial test zone
    - Development
      - Less of an issue
    - Manufacturing/Installation
      - Somewhat of an issue
    - Operation/Maintenance
      - BIG issue
- Point: Different tools needed for different phases

2005 Activities

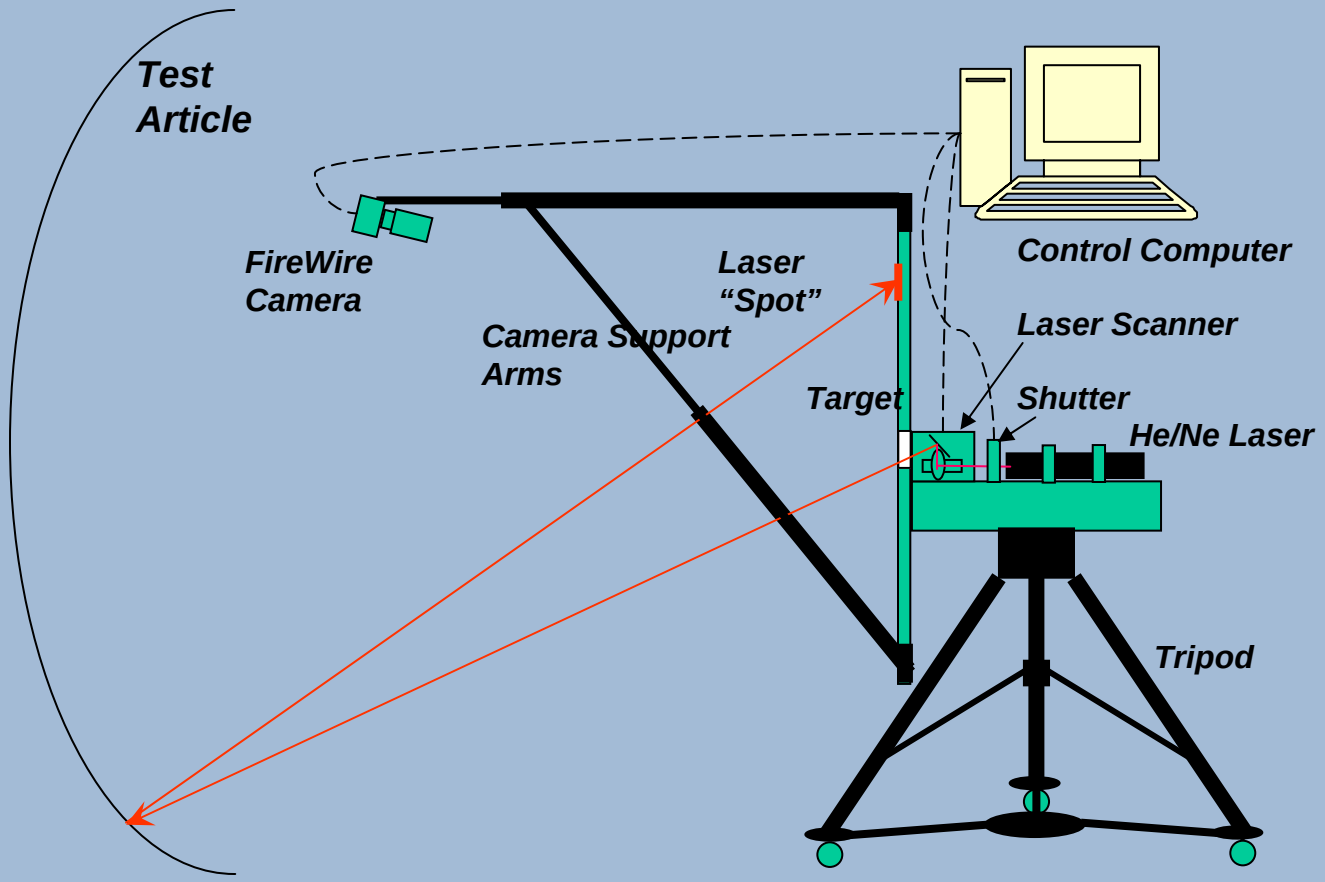
- Focused on development and manufacturing/installation phases
  - Solargenix Advanced Parabolic Pilot Project
  - Industrial Solar Technology (IST) Parabolic Trough Technology Development Project
- Improve/Modify/Update VSHOT for Parabolic Trough Field Measurements
- Use VSHOT to quantify for both Solargenix and Industrial Solar Technology designs
  - Mirror Optical Accuracy
    - Mirror contour
    - Mirror specularity
  - Mirror Panel Alignment
    - Tilt
    - Position

Field Ready VSHOT

- Laptop controlled
- Updated development environment
- National Instruments Image Acquisition and Processing libraries
- Firewire camera implementation
- Equipment organization and shipping container
- Fixed camera supports/target calibration

VSHOT

- Originally designed for point-focus concentrators
- Adapted for line-focus optics (samples one vertical slice at a time)
- Measures bi-directional surface slope, fits data to user defined shape, reports errors relative to that shape



Solargenix Advanced Parabolic Trough Pilot Project

- Leveraged off of the Nevada South West Energy Partnership
- Focuses on Manufacturing and Installation Phase

Primary Objective

SOLARGENIX ENERGY
Formerly Duke Solar Energy

Full-Scale Testing….

…. Prior to 50 MW Plant

History and Linkage to National Program

- 4-yr USA-Trough development (DOE/NREL)

- Major advances, but need full-scale tests
  - New lightweight structure
  - New drive
  - New controls
  - New concrete piers and support pedestals
  - New ball joint assemblies

Project Hardware

- Advanced low-cost bearings installed
- Construction completed (All 24 space frames: 2 SCAs)
- Controllers and drives installed

VSHOT Test Objectives

- Provide Solargenix with data on mirror optical errors
- Validate the “new and improved” field ready VSHOT system
- Lessons learned and identification of improvements to assist future testing

First Round of Tests
Starnet Spaceframe
February ‘05

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable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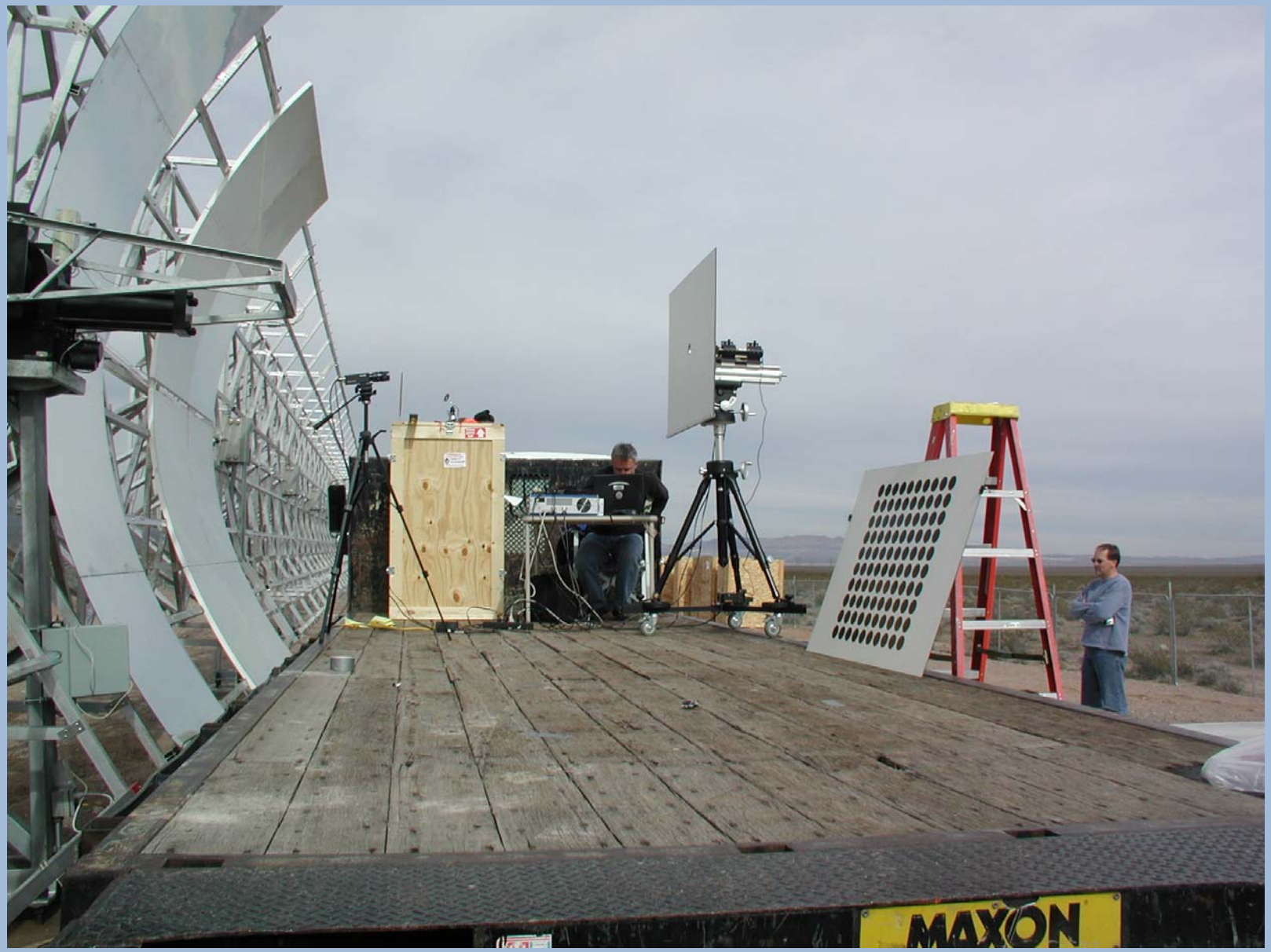
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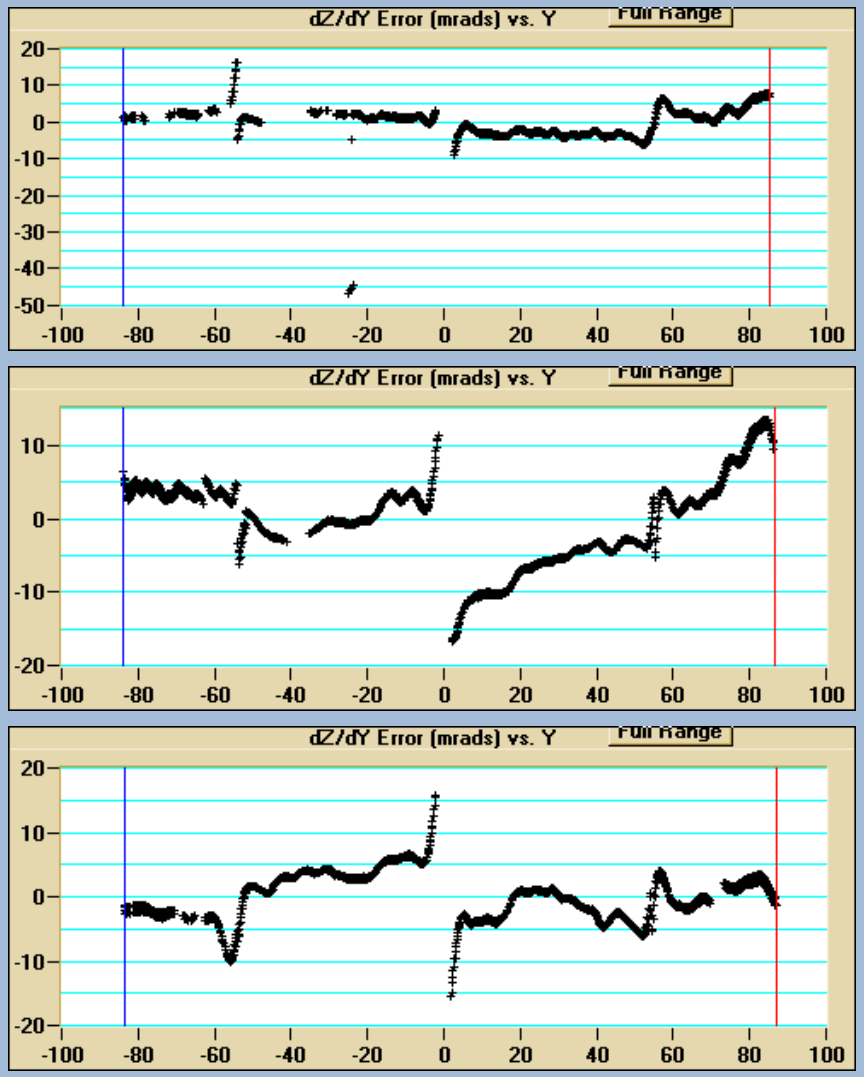
Initial Test Results (Feb. ’05)

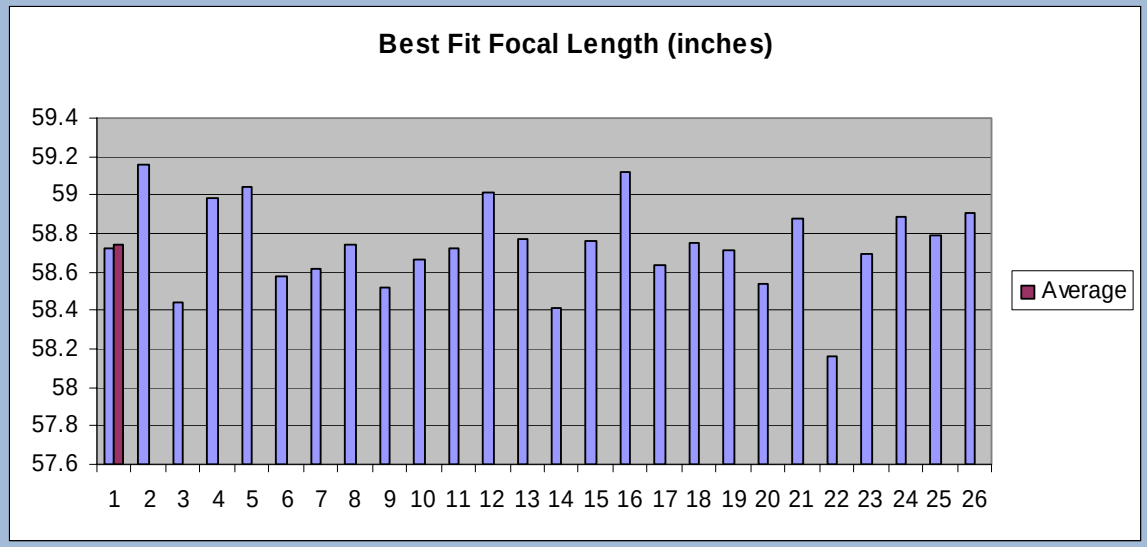
- Only tested 3 columns of glass mirrors
- Not enough data to come to any conclusions regarding mirror optical accuracy.
- Validated outdoor testing

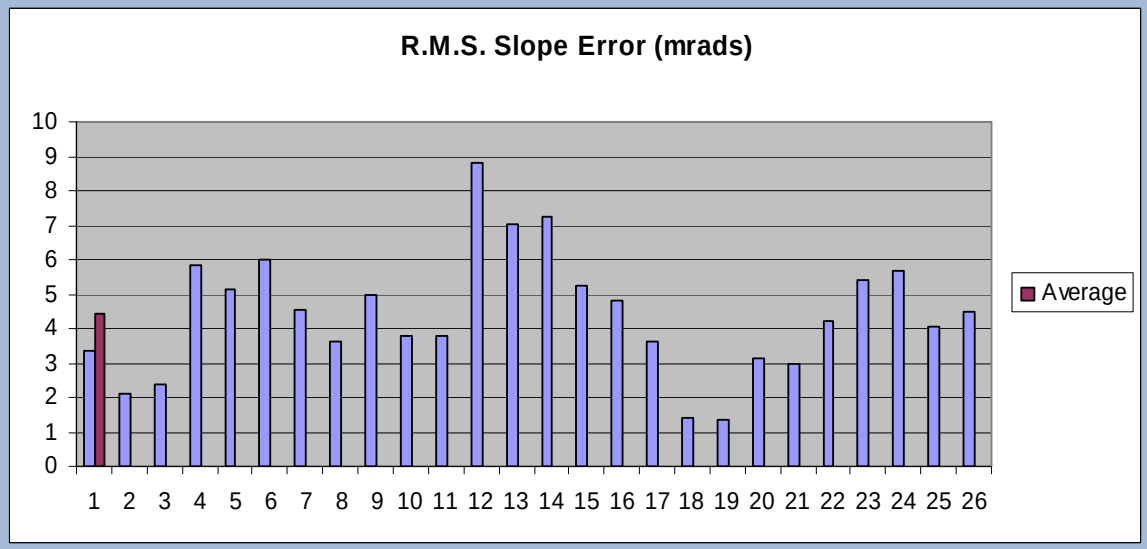


2nd Round of Tests (July ’05)

- Fully populated SCA (6 Starnet modules on each side of drive)
- Randomly select two mirror columns per module (24 VSHOT profiles total)
- Use data to quantify SCA twist and overall r.m.s optical slope error
- Identify specific contributors to slope error (i.e. mirror panel distortion and/or misalignment)

- Average r.m.s. slope error = 4.4 mrad
- Average best fit focal length = 58.73” compared to design of 58.66”





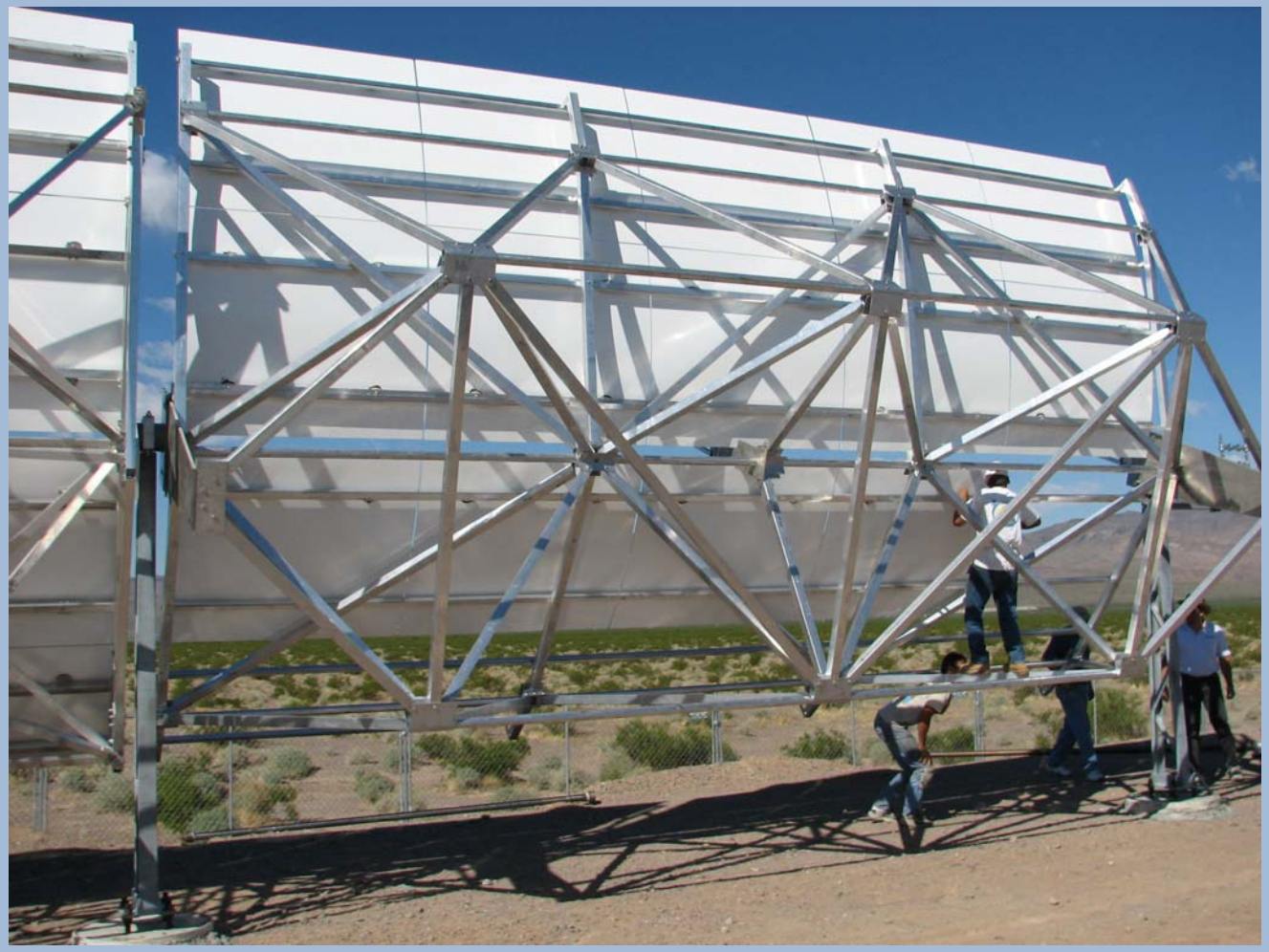
Conclusions (StarNet Spaceframe)

- Misalignment and distortion contribute to optical error
- 4.4 mrad r.m.s. slope error not unreasonable, but improvements could be made, especially in mirror panel misalignment
- Cannot say much about SCA twist due to drive drift during during test period. More tests necessary.

Gossamer Spaceframe

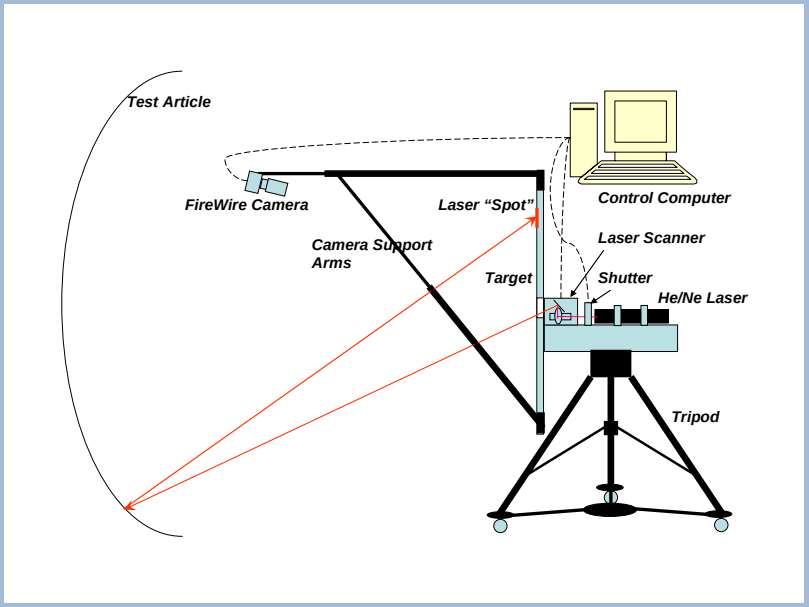
- Solargenix sought out new supplier for spaceframe
- Potential for lower assembly cost and better performance
- Tests on new modules perfomed in September, October ‘05

Gossamer Spaceframe



VSHOT Improvements

- Camera integrated into target
- Leveling tools built into tripod
- Much faster data acquisition now possible



Gossamer Results

- R.M.S. Slope Error approaching 3.0 mrad
- Based partly on these results Solargenix has decided to use Gossamer spaceframes in their 64 MW El Dorado Valley plant.

Industrial Solar Technology Parabolic Trough Development Project

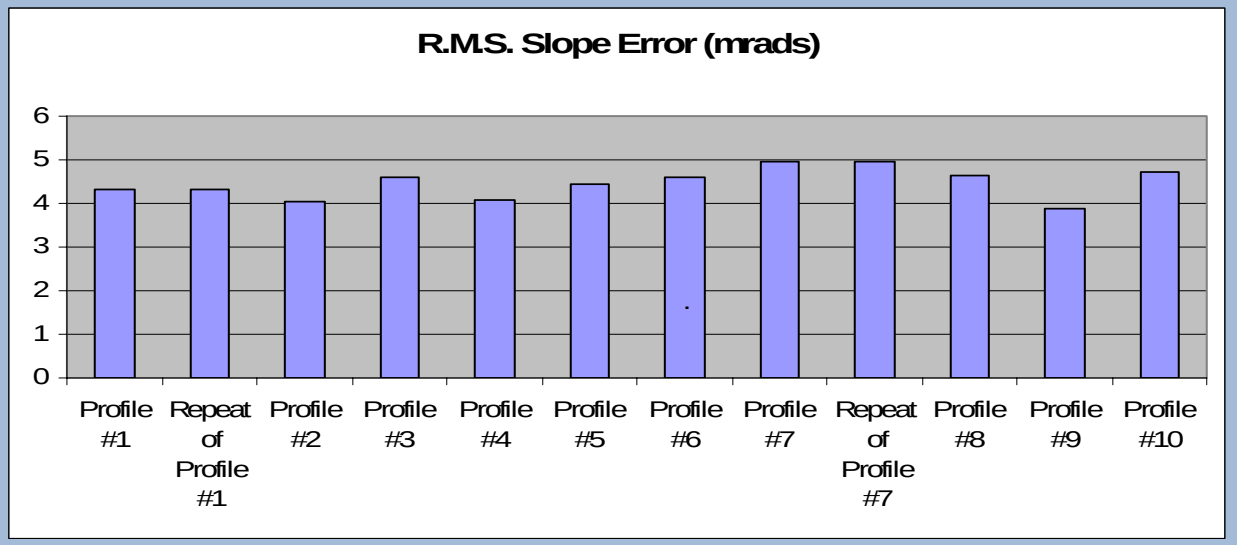
- IST scaling up their unique structural concentrator design to LS-2 type dimensions
- Requires optical characterization baseline of their existing product
- VSHOT used to provide data

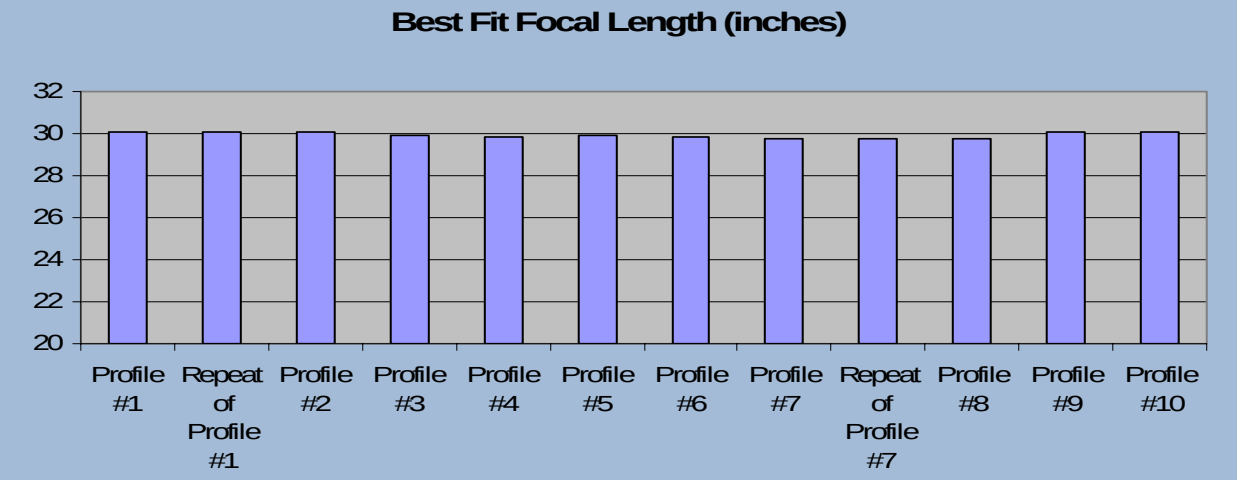
Industrial Solar Technology Parabolic Trough Development Project

- Current IST design is continuous surface reflector (no individual mirror panels)
- Concentrator module itself provides structural stiffness along module length (no support structure required)
- 10 VSHOT profiles taken along length of baseline IST module (using polymer film reflector) to characterize optical performance

Initial Module Results

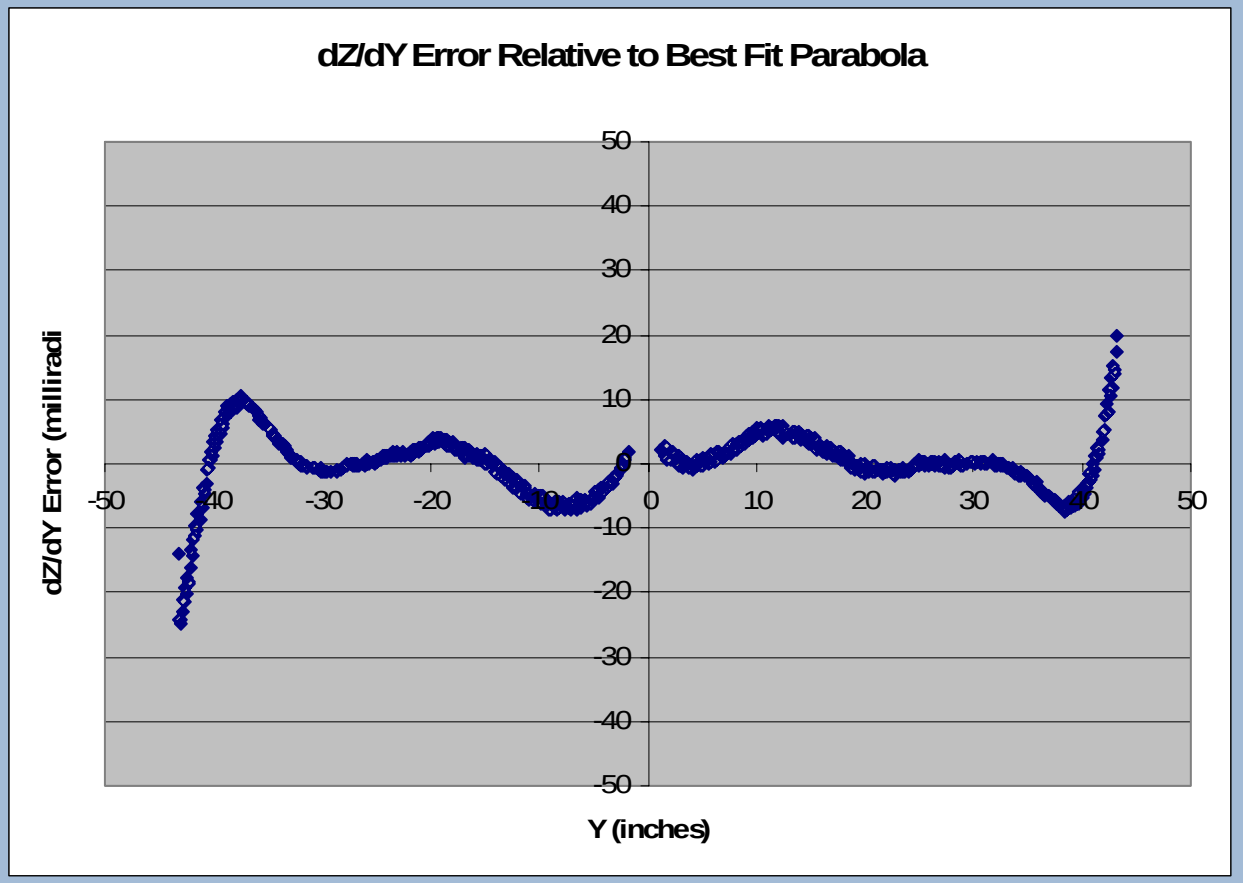
- Average r.m.s. slope error = 4.46 mrads
- Average best fit focal length = 29.92” compared to design of 30.06”
- Very consistent along module length





Results

- Consistent profile along module length
- Exhibits a flattening or parabolic curve at rims
- Better machining tolerances could improve this considerably



Recent results

- Two new improved modules assembled and tested
- Significant improvement in slope error ~ 3.4 mrad r.m.s.
- Closer to design focal length of 30.35”